Improved Traceability of Mission Concept to Requirements Using Model Based Systems Engineering

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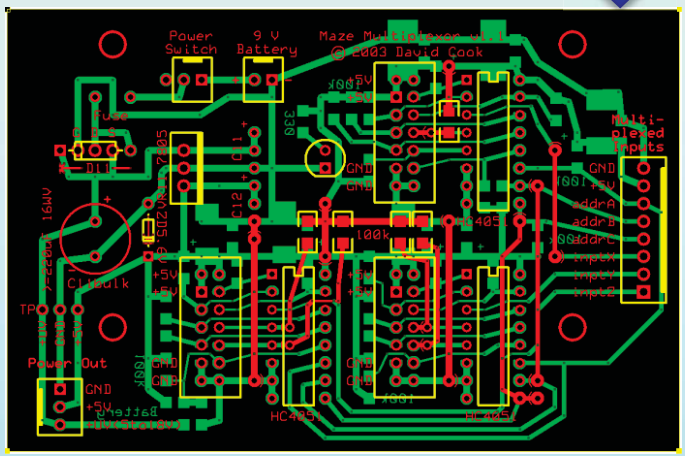
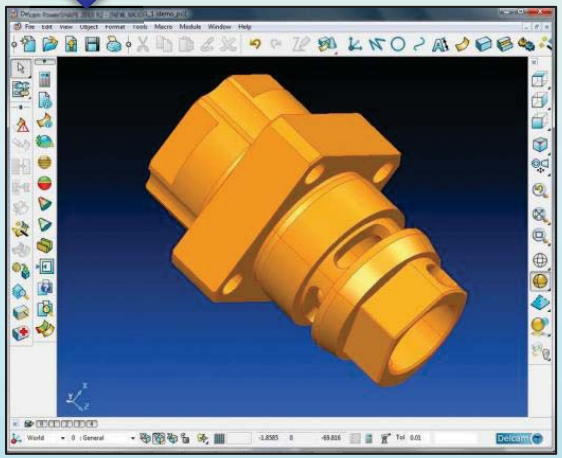
Outline

- Background
- Thesis Objective
- Methodology
- Results
- Implications of Research

Background

Model-Based Approach





Wikipedia and Google Image Search

Background

"Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases."

- *Systems Engineering Vision 2020*, INCOSE-TP-2004-004-02, September 2007

Background

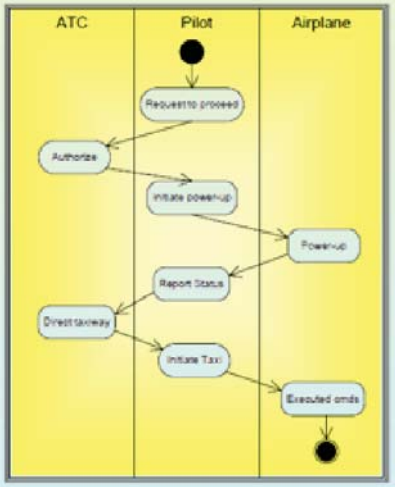
Document-Based SE (DBSE) vs. MBSE

Past

SE Artifacts

- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



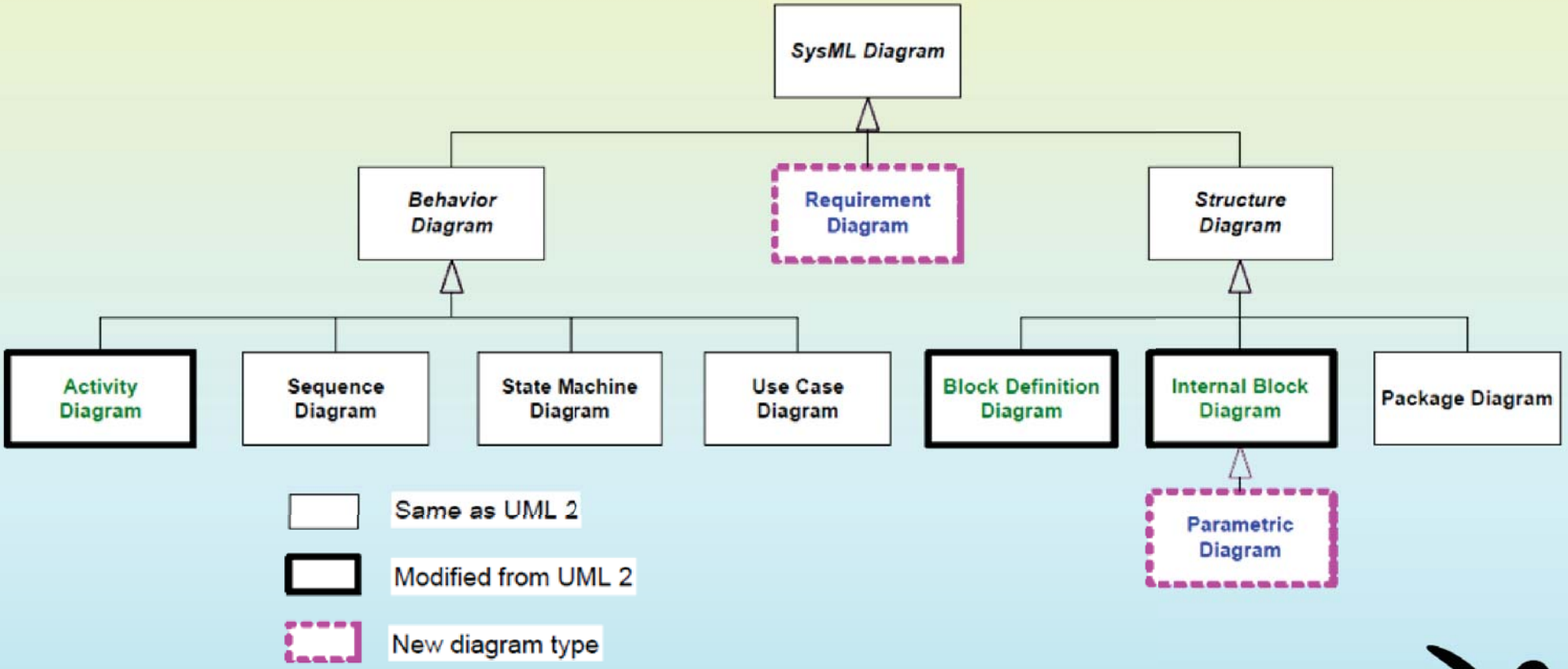
Document centric

Model centric

INCOSE Model Based Systems Engineering (MBSE) Initiative, June 2007

Background

Systems Modeling Language (SysML)



Background

- Perceived Benefits of MBSE
  - Communications
  - Development risk
  - Quality
  - Productivity
  - Leveraging model across life-cycle
  - Knowledge transfer

A Practical Guide to SysML, 2nd Edition, 2012

Background

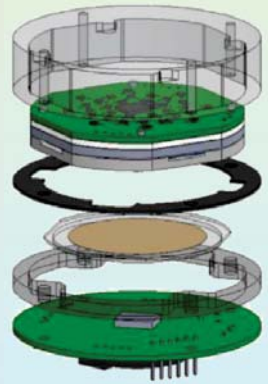
- Research
  - Documentation of early modeling efforts
  - Descriptions of potential benefits from modeling
  - Lack of work presenting direct evidence of MBSE benefits

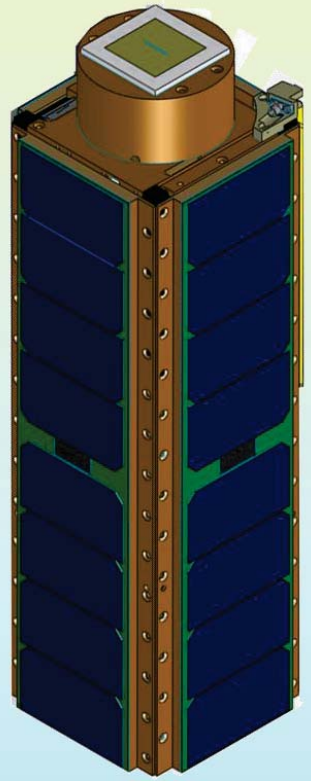
Thesis Objective

Demonstrate MBSE utility in tracing mission concept to requirements

Methodology

- Model NASA Ames SporeSat
  - 3U CubeSat
  - Studies fern spore growth in varying gravity environments

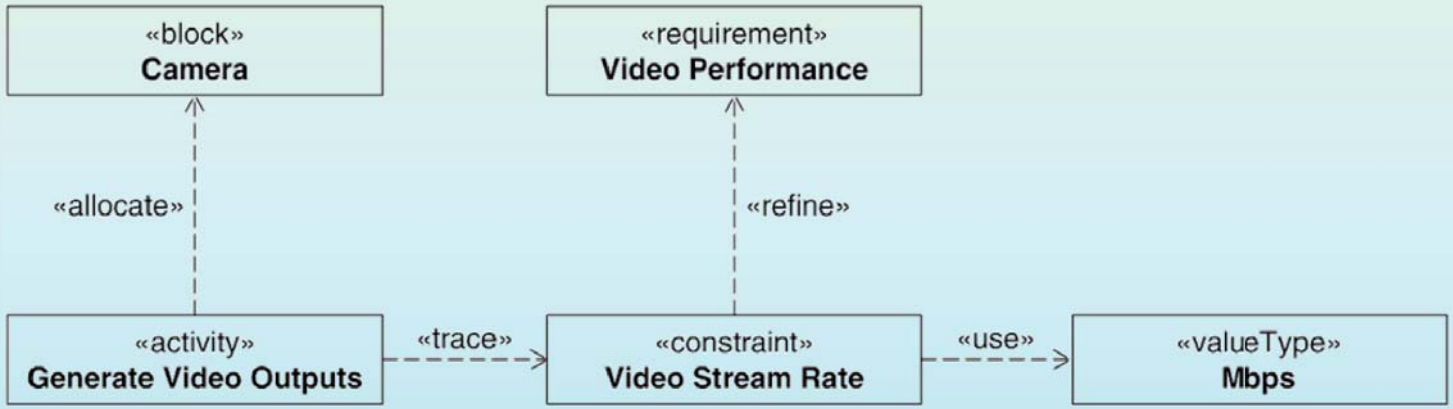




SporeSat NASA Fact Sheet, FS #2013-04-04-ARC, 2013

Methodology

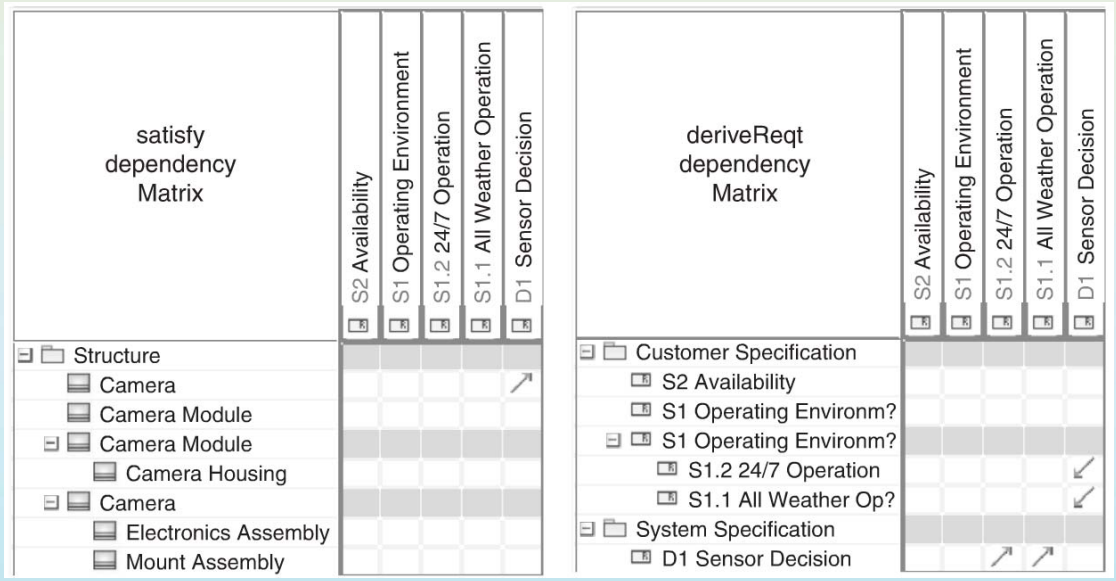
- Create Mission Model
  - Mission Architecture and CONOPS
  - Mission Requirements
  - Dependency relationships



A Practical Guide to SysML, 2nd Edition, 2012

Methodology

- Analyze
  - Completeness and ambiguity of requirements
  - Consistency between requirements and design



A Practical Guide to SysML, 2nd Edition, 2012

Methodology

3 SPORESAT SCIENCE REQUIREMENTS

3.1 General Requirements

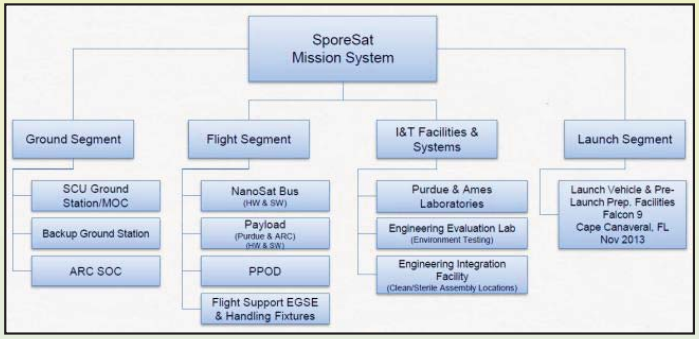
The SporeSat systems shall comply with
to ensure experiment viability.

3.1.1 Experiment Configuration

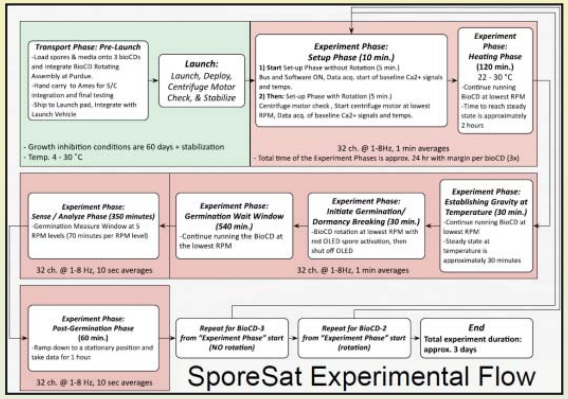
3.1.1.1 Artificial Gravity (Acceleration) Pr

Means shall be provided to artific
supports the immobilization, germ
multiple spores of Ceratopteris ric

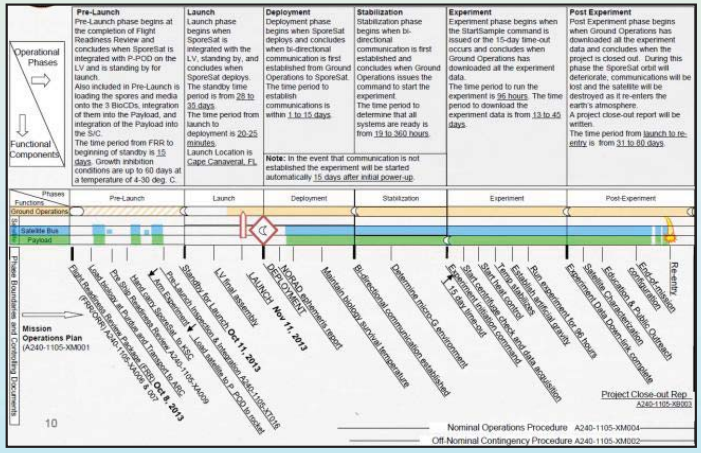
Requirements (Document)



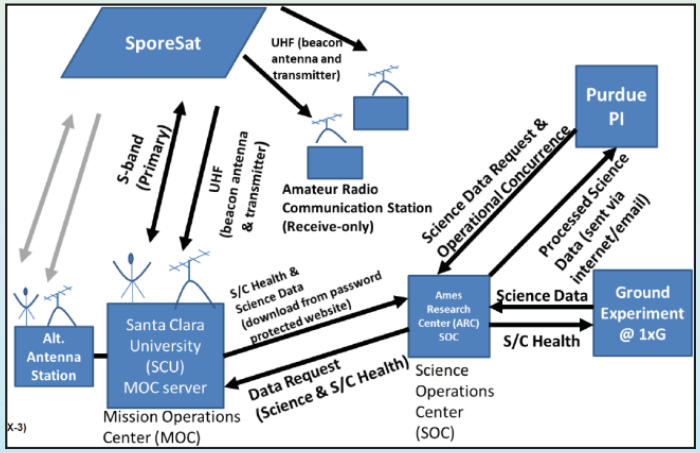
Architecture (Powerpoint)



Experiment FFBD and Timeline (Powerpoint)



Phase Description and Timeline (Powerpoint)

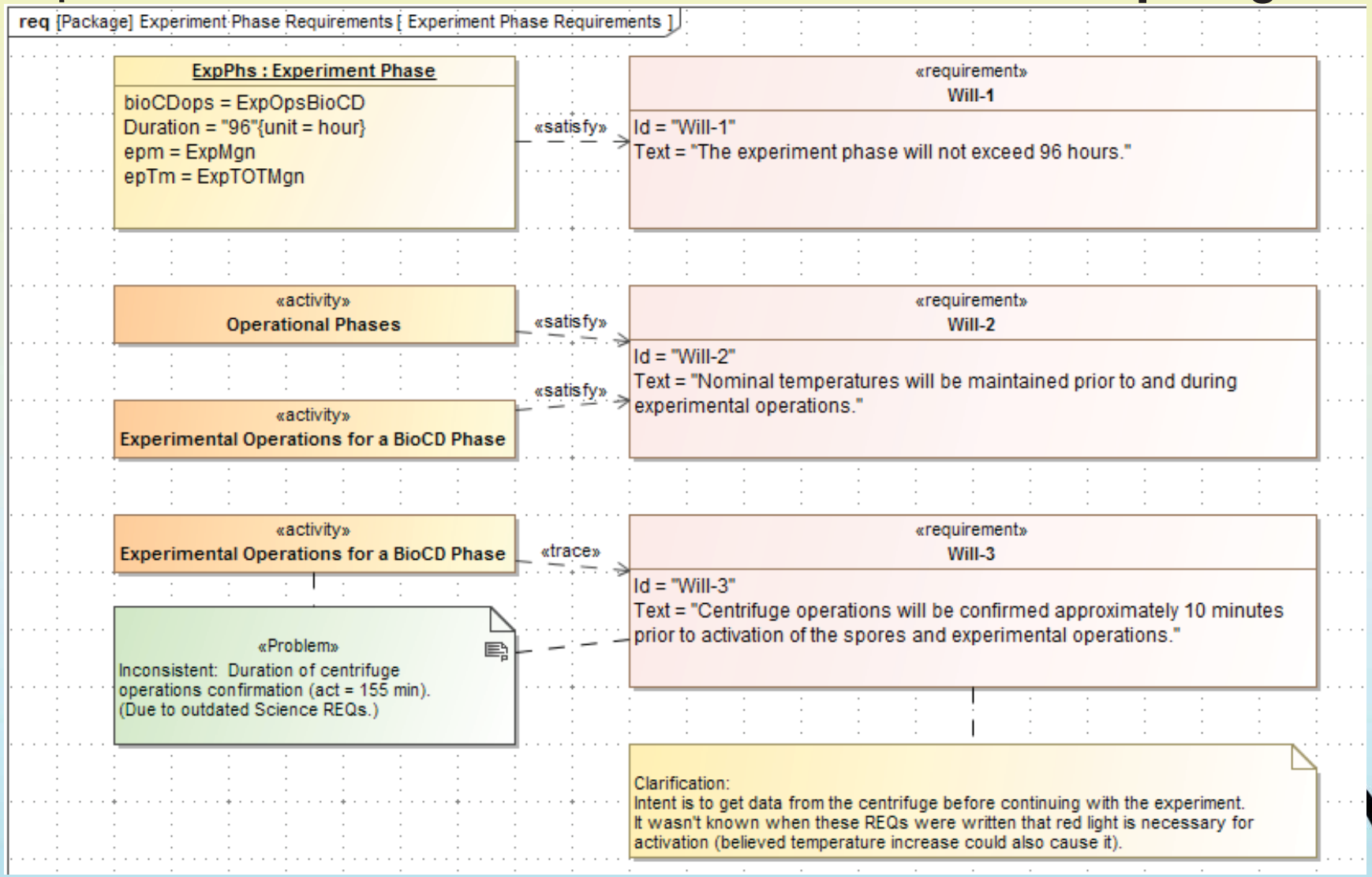


Communication Architecture (Powerpoint)

Results

Document:
Requirements

Model:
req Diagram



Results

Document:
Requirements

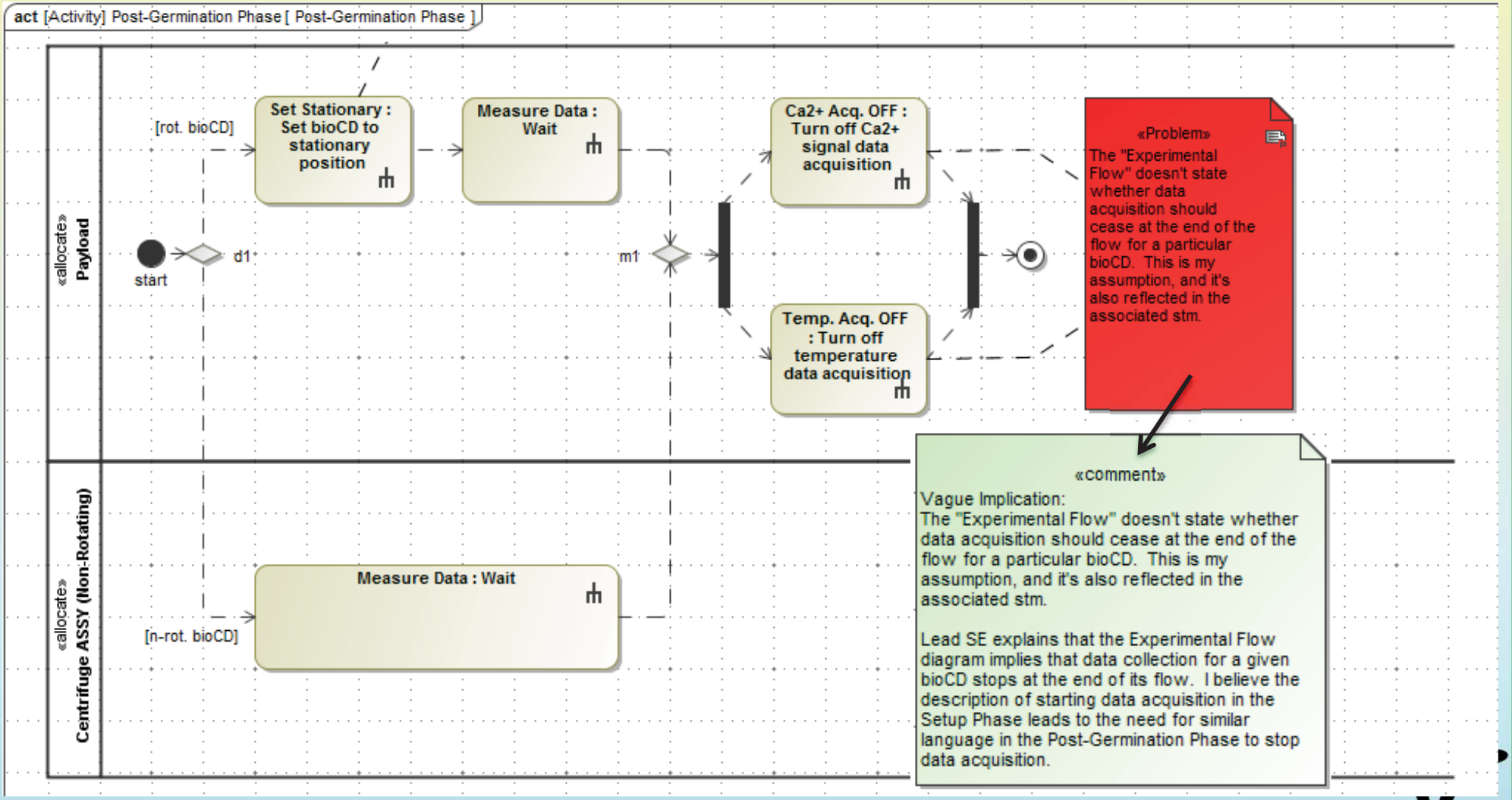
Model:
Satisfy Matrix

	S41 Baseline Exp...	S46 Ca2+ Differ...	S45 Control of Ar...	S45.2 Maximum ...	S45.1 Minimum P...	S49 Data Acquisi...	S54 Data Acquisi...	S43 Experiment ...	S53 Experimental...	S42 Spore Growt...	S42.2 Spore Gro...	S42.1 Spore Gro...	S42.3 Spore Gro...	S50 Time Spacing...	S52 Time Spacing...	S51 Time Spacing...	S44 Variable Gra...	S48 Voltage Data...	S47 Voltage Data...	Will-1 Will-1 [Scie...	Will-2 Will-2 [Scie...	Will-3 Will-3 [Scie...	Will-4 Will-4 [Scie...	Will-5 Will-5 [Scie...
Behavior		1						1									1				2	1	1	
Structure	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	2	3	1				1
Launch Vehicle																								
Lower Level Detail		↗									↗	↗												
Magnet																								
Main Antenna																								
Main Battery																								
Main Transceiver																								
Master PCB																			↗					
Mission Team																								
Motor ASSY				↗	↗																			
Payload								↗																
Payload Interface PCB																								
Payload PCB							↗		↗															

Results

Document:
Phase Description

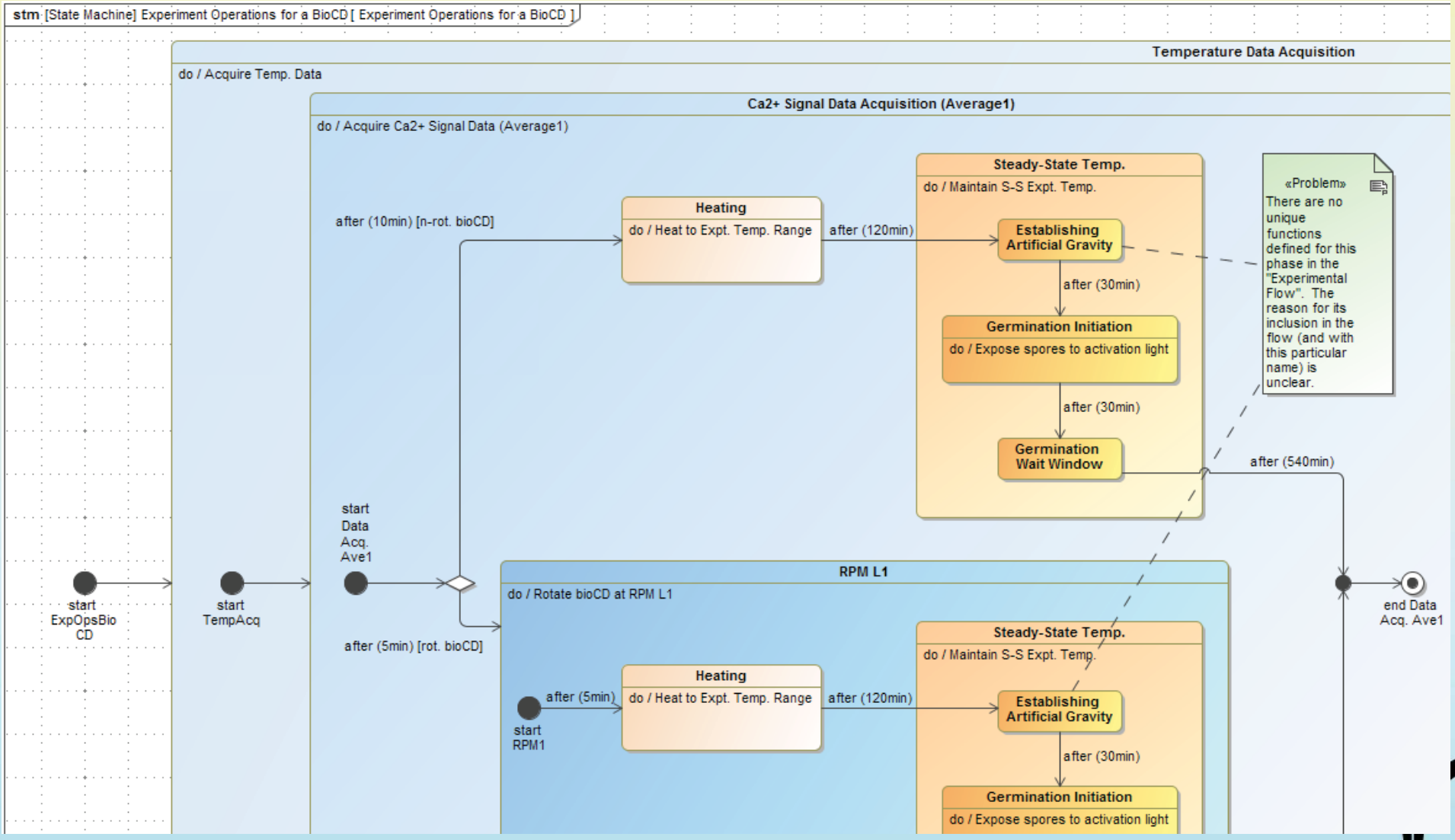
Model:
act Diagram



Results

Document:
Experiment Timeline

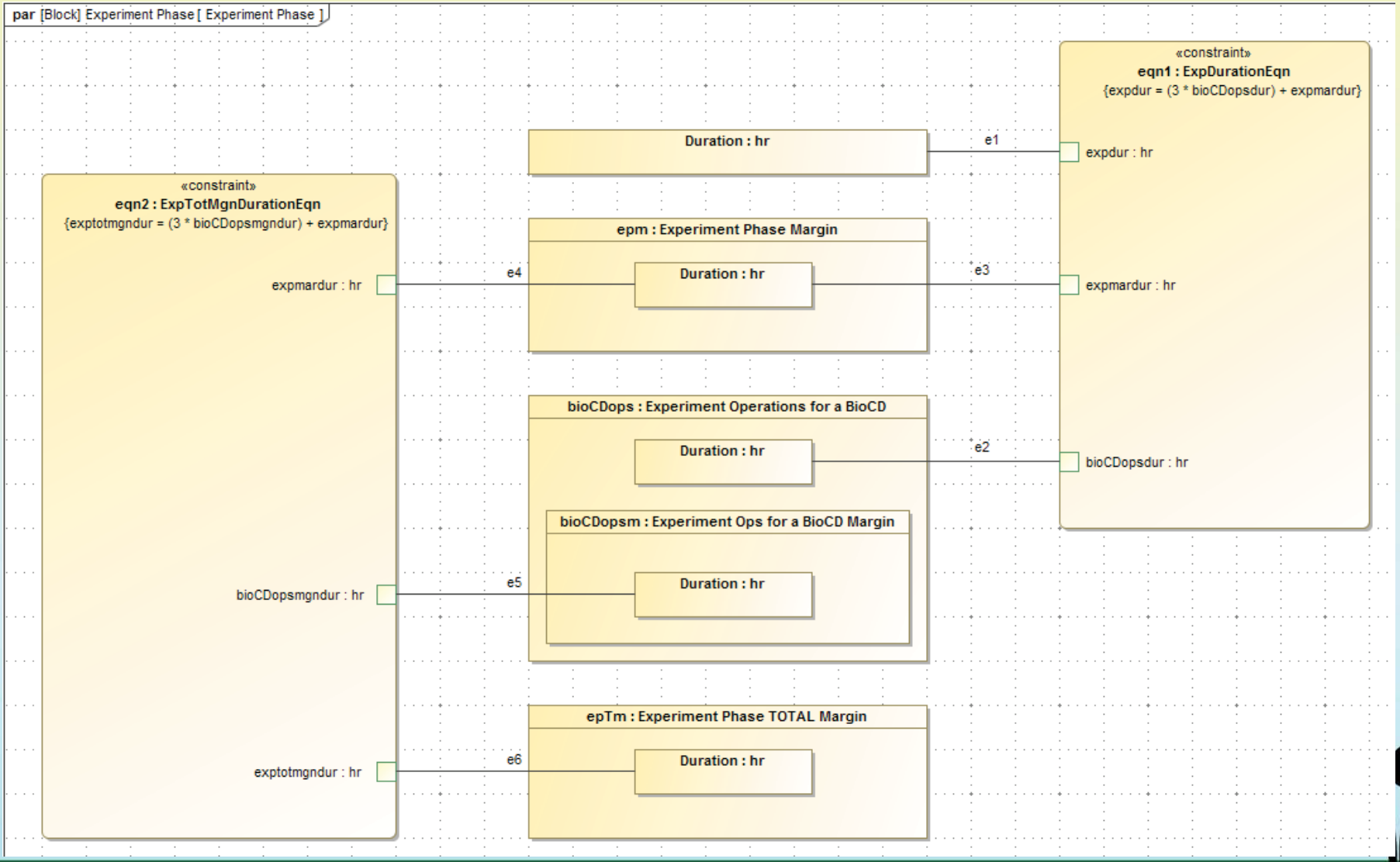
Model:
stm Diagram



Results

Document:
Experiment Timeline

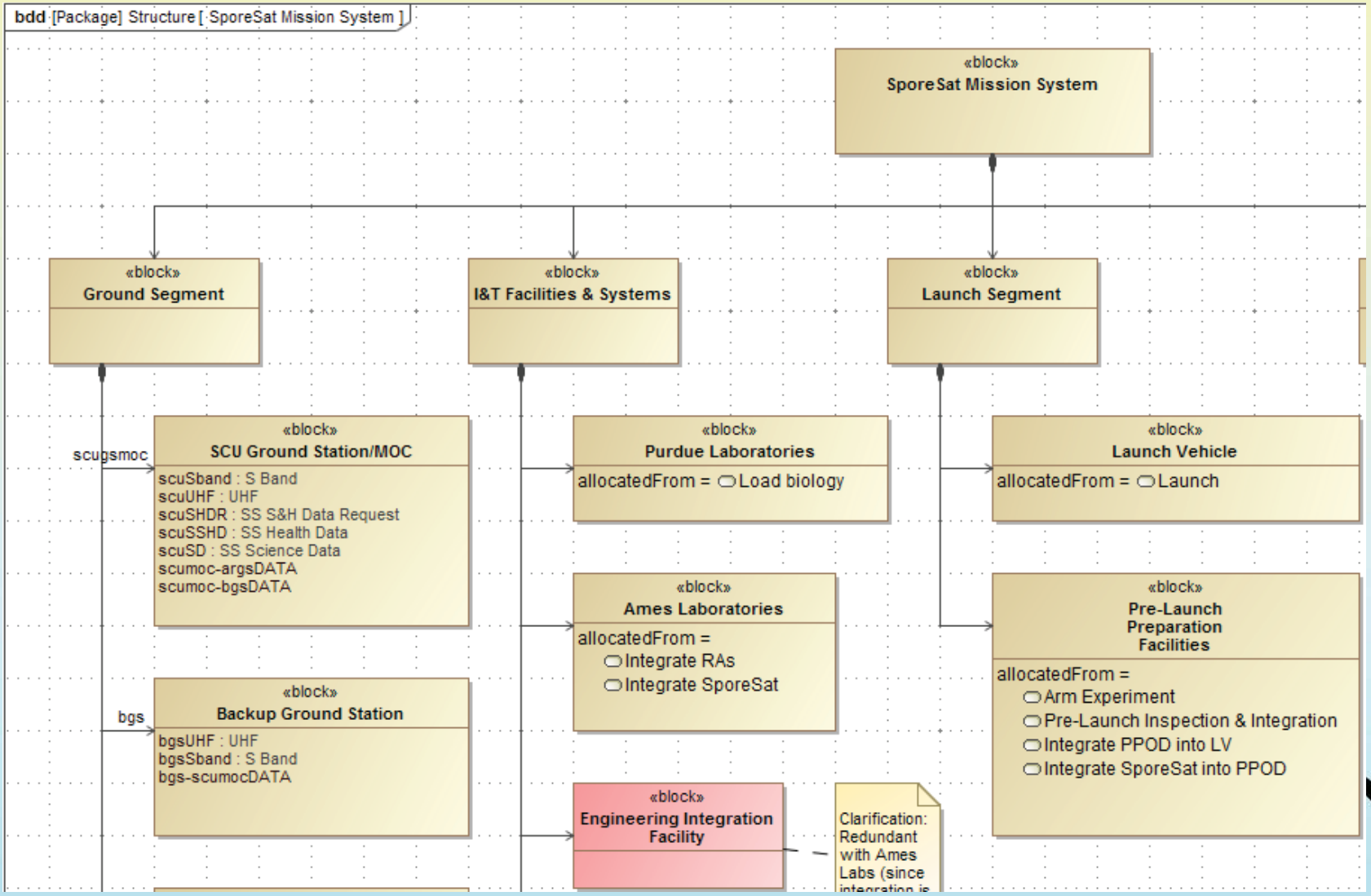
Model:
par Diagram



Results

Document:
Architecture

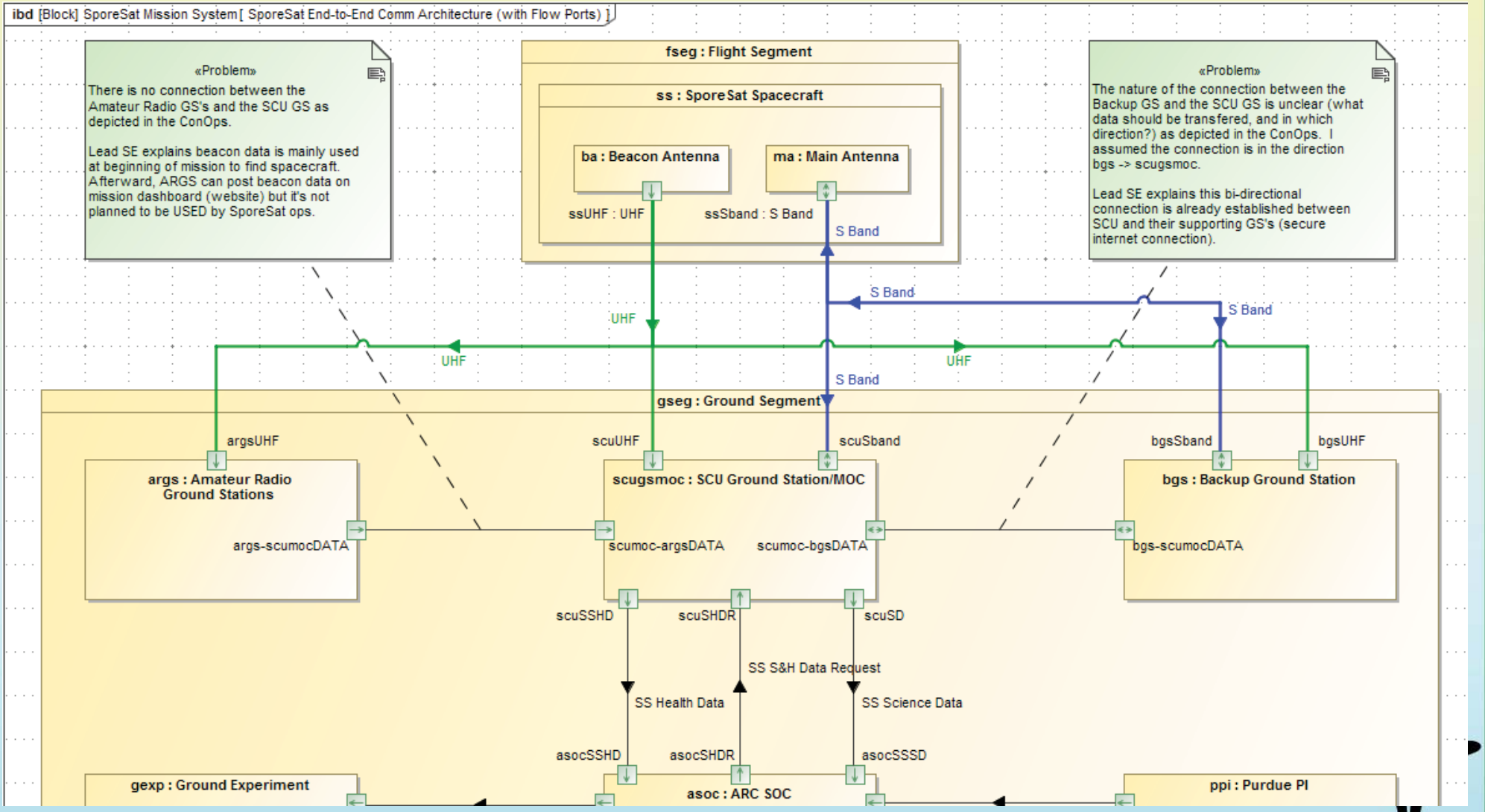
Model:
bdd Diagram



Results

Document:
Comm. Architecture

Model:
ibd Diagram



Results

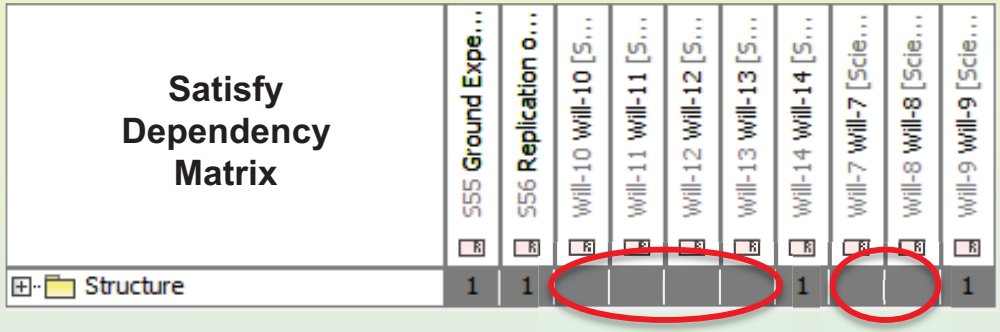
Tracked Issues

Issues	
Total	41
Resolved	14
Unresolved (issues with Requirements / ConOps)	27

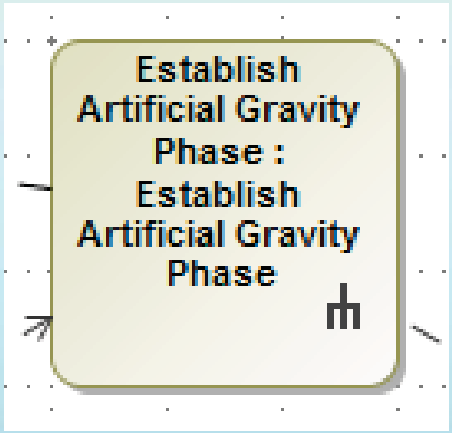
Unresolved	
Vague Implication	2
Not verifiable as written	3
Redundancy	4
Nomenclature Inconsistency	5
Outdated Documentation	13

Results

Issue: Ground Experiment Requirements ↔ ConOps

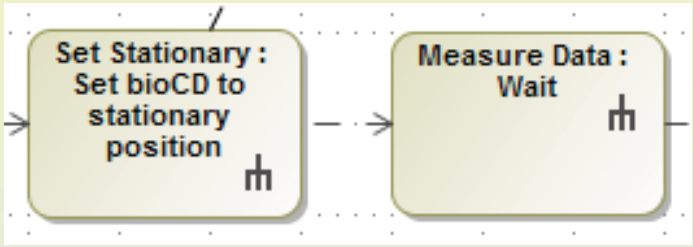


Issue: ConOps Missing Information

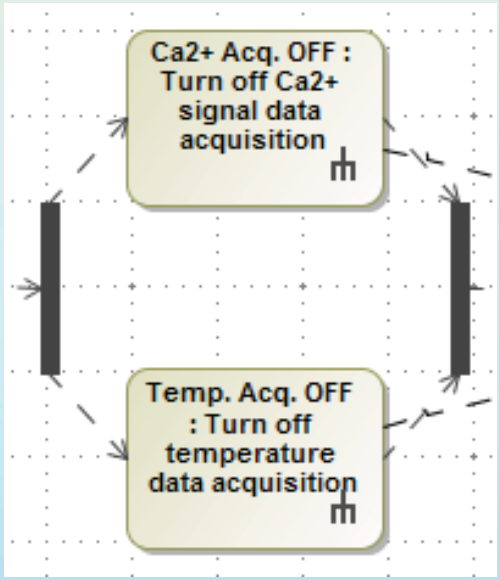


Results

Issue: ConOps ↔ Experiment Phase Requirements

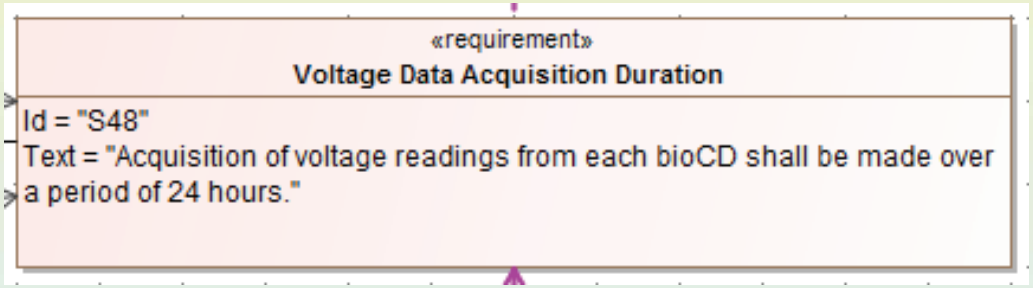


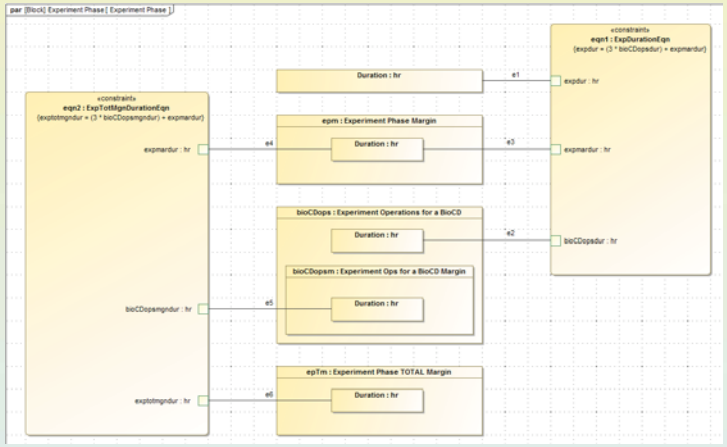
Issue: ConOps Missing Information



Results

Issue: ConOps ↔ Experiment Phase Requirements Inconsistencies





Experiment Phase Duration:

- Experimental Flow Diagram → 72 hours
- Operational Phase Diagram → 96 hours
- Experiment Phase Requirements → ≤ 96 hours

Results

- Issues with SysML / Modeling Tool
  - No smarts to the relationships between requirements and/or model elements
  - Time representation

Implications of Research

MBSE

YEA?

NAY?

Future Work

- Determine metrics to measure MBSE benefits quantitatively
- Study MBSE approach in various settings
  - Government vs. Industry vs. Academia
  - Large vs. small missions
  - ROI for short and long term
- Study MBSE benefits when used throughout full life-cycle